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Jeroen P.J. de Jong
Mark Freel

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emailaddress corresponding author	jjo@eim.nl
address	EIM Bredewater 26 P.O. BOX 7001 2701 AA Zoetermeer The Netherlands Phone: +31 79 343 02 00 Fax: +31 79 343 02 03 Internet: www.eim.nl

Geographical distance of innovation collaborations

Jeroen P.J. de Jong[1] and Mark Freel[2]

We empirically explore the geographical distance of innovation collaborations in high tech small firms. It is supposed that absorptive capacity is a key determinant. Drawing on survey data from a sample of 316 Dutch high-tech small firms, engaged in 1 245 collaborations, we find most partners to be 'local'. However, controlling for a variety of potential influences, higher R&D expenditure is positively related to collaboration with more distant organisations.

In the academic literature, there is increasing consensus that a firm's embeddedness in a network of interfirm relations matters for its economic and innovative performance (Gilsing et al., 2008). Simply put, few firms appear able to innovate alone (Tether, 2002). Moreover, and for some time, the benefits of collaborative innovation have been thought to apply particularly to small firms (e.g. Rothwell and Dodgson, 1991). The caricature of small firms as behaviourally advantaged but materially constrained (Nooteboom, 1994; Rothwell, 1983) has frequently seen networks presented as the logical means to ameliorating resources constraints, whilst preserving behavioural advantages (Hewitt-Dundas, 2006). Certainly there is plenty of empirical evidence to support the importance of involvement in networks for innovation in small firms – from the classic accounts of the new industrial districts of the Third Italy (e.g. Becattini, 1978) to more recent empirical studies (e.g. Fukugawa, 2006). Innovation-related collaboration has also attracted the attention of policy makers. Bougrain and Haudeville (2002), for instance, note a growing preference for network promotion policies (over those that provide direct financial assistance) within OECD economies. Undoubtedly, much of the inspiration has been provided by the systems of innovation literature (e.g. Lundvall, 1992). The suggestion that underinvestment in R&D may not solely be a consequence of market failure, but may also be caused by a lack of interaction between innovation actors, has proven to be particularly attractive to European policymakers struggling to meet the Barcelona targets.

A central feature of the more popular expositions of innovation systems is the treatment of 'space'. Whether systems are bounded at the local, regional or national level, the implication is that proximity matters. Empirically, studies typically indicate a distance decay function in communication, of varying extent (Howells, 1999). In this sense, the importance of proximity is thought to 'reflect the linguistic and geographic constraints imposed by person-embodied exchanges and transfers of tacit knowledge' (Patel and Pavitt, 1994: p. 218). Geographical proximity makes it more likely that firms will encounter potential collaboration partners and, after the collaboration takes off, it enables personal and more frequent contacts easing the transfer of tacit knowledge and offering better opportunities to resolve emerging conflicts. For policy makers the proposed significance of geographical proximity has been a key argument in the implementation of popular policies focussing on geographical clusters (Fritsch and Stephan, 2005).

[1] EIM Business and Policy Research, Zoetermeer, The Netherlands. E-mail jjo@eim.nl.
[2] Telfer School of Management, University of Ottawa, Canada.

More recently however the necessity of geographical promixity has been questioned (e.g. Torré and Rallet, 2005). Underpinning this, is the regularity with which empirical studies of innovation-related cooperation record a higher incidence of extra-local linkages over local linkages, suggesting that firms draw from innovation sources at a variety of spatial scales (e.g. Arndt and Sternberg, 2000; Kaufmann and Tödtling, 2000). However, the ability to identify partners, to transfer knowledge and resources and to manage relationships at a distance is unlikely to be easily acquired. Rather, firms are likely to have to make conscious investments in such capabilties – principal amongst which will be investments in absorptive capacity. Here too, small firms may be particularly disadvantaged. Limited R&D expenditures and a focus on exploitation rather than exploration may lead small firms to be more dependent upon immediate local partners.

This paper adds to the literature by exploring the connection between firms' absorptive capacity and the geographical distance to their collaboration partners. This connection has been proposed before (Torré, 2008) but not been demonstrated empirically. As absorptive capacity is a contingent factor in opportuntity recognition, alliance formation and the accumulation of resources available through social networks (Soh and Roberts, 2005), we hypothesise that investment in absorptive capacity may help compensate for a lack of geographical proximity in innovation-related collaboration. Drawing on survey data of 316 Dutch high-tech small firms, our hypothesis is confirmed, suggesting a different emphasis for both business and industrial policy. We hereafter elaborate on our hypothesis, data, methods and results, and conclusions and implications.

THEORY

In a well received review, Boschma (2005) argues that other forms of proximity may frequently substitute for geographical proximity. He distinguishes between five forms of proximity – geographical, cognitive, organizational, social and institutional. Boschma suggests that the importance of geographical proximity cannot be assessed in isolation, but should always be examined in relation to other dimensions of proximity that may provide alternative solutions to the problem of communication and coordination in collaborative projects. Importantly, he proposes that geographical proximity is neither a necessary nor a sufficient condition for effective innovation collaboration, but may facilitate innovation largely through strengthening other dimensions of proximity. Morever, whilst geographic, social, organization and institutional proximities increase the likelihood of partners coming togther, it is cognitive considerations that determine whether or not interactive learning processes may take place (Boschma, 2005, p. 71).

Boschma (2005) defines cognitive proximity to be a function of the similarity between organisations' knowledge bases. Simply, organisations are cognitively proximate where they posess similar market and technological competences. And, build on shared experiences and understandings, cognitive proximity facilitiates effective communication and collaboration. One can identify clear parallels between this elaboration of cognitive proximity and the concept of 'absorptive capacity' (and this is also explicitly discussed by Boschma). Both start from the proposition that organizational search processes are constrained by existing knowledge. In this way, learning is seen to be cumulative, self-reinforcing and path dependent, such that it is easier to recognize and evaluate knowledge (and the returns to learning are higher) in areas of prior familiarity (Levinthal, 1996). Or, to restate, a firm's ability to recognize, evaluate, acquire and use external knowledge – its absorptive capacity – is a function of its prior related knowledge (Cohen and Levinthal, 1990). And, to the extent that studies indicate an increasing dependence of innovation on extramural knowledge, absorptive capacity represents an important component of a firm's ability to create new knowledge. However, to the extent that the development of current knowledge requires resources, resource constrained small firms are likely to have both a narrower and shallower absorptive capacity than their larger peers (Cohen and Levinthal, 1990).

However, our concern here is not simply with absorptive capacity and the acquisition of external knowledge or, with absorptive capacity and the propensity to engage in innovation-related collaboration – both of which have been firmly established in the literature (e.g. Bougrain and Haudeville, 2002; Lane et al., 2001). Rather, our concern is with the spatial dimension of collaborations and with the potential for a developed absorptive capacity to increase the effective reach of search and acquisition processes in small firms. As Torré (2008) notes: '…firms with higher absorptive capacities within a cluster are those that are most likely to establish linkages with external sources of knowledge. This is explained on the basis of cognitive distances between firms and extra-cluster knowledge, so that firms with high absorptive capacities are considered more cognitively proximate to extra-cluster knowledge than firms with lower absorptive capacity' (p. 874).

Firms in the same industry, occupying the same locale, are likely to be higly cognitively proximate on the basis of shared experiences and understandings. However, excessive cognitive resemblance may limit innovation opportunities, since there would be little left to learn (Boschma, 2005; Nooteboom, 1999). Rather, to access the cognitive diversity that is required for innovation, firms may have to venture further afield. Their ability to do this is likely to be contingent upon the strength of their absorptive capacity, as a highly developed absorptive capacity allows firms to increase their cognitively proximity to geographically distant potential partners.

In sum, when firms' absorptive capacity is low, geographically proximate collaborations may be their only option. When cognitive gaps cannot be bridged, geographical proximity may be a necessary condition to transfer tacit knowledge. In contrast, high absorptive capacity is anticipated to diminish the cognitive distance to other innovating actors, enabling firms to collaborate for innovation at greater geographical distance. It enlarges the 'innovation bandwith' in which firms may operate. To the exent that cognitive proximity implies that collaboration partners are alike in terms of their domain-specific, tacit knowledge, so many of the learning costs implied by physical distance may be reduced. Moreover, in addition to improving firms' ability to collaborate with geographically distant partners, highly developed absorptive capacities are likely to see firms quickly exhaust their local learning opportunities (Drejer and Vinding, 2007). Accordingly, we hypothesize a positive connection between firms' absorptive capacity and the geographical distance to innovation-related collaboration partners.

DATA

We test our hypothesis drawing on data collected via a survey of high-tech small firms in the Netherlands. While these firms are the primary target of most innovation policy instruments their actual innovation features are poorly identified in standard Dutch statistics. Therefore, in the spring of 2006 the Dutch Ministry of Economic Affairs commissioned a survey to map their innovation and performance characteristics. We were able to access its database for our current analytical purposes.

The survey defined high-tech small firms as those that 1. had no more than 100 employees; 2. were actively engaged in R&D; and 3. had developed new technology-based products in the past three years (Grinstein and Goldman, 2006). Since there was no suitable sampling frame (high-tech firms may inhabit apparently low-technology industries and, equally, high-tech industries are not comprised exclusively of firms satisfying all three criteria) a two-phase sampling process was conducted. Firstly, an initial database was obtained from the Dutch authorities with the contact details of 2 111 recent applicants to innovation subsidy schemes. Telephone interviews were done to screen whether they satisfied the above-mentioned criteria. This effort resulted in a list of 675 high-tech small firms. These were then invited to participate in an internet survey to map their innovation and business performance characteristics in detail. Altogether 379 firms participated, a response rate of 56%. Respondents were all small business owners or general managers with a good overview of all aspects of the firm. For our current analytical purposes, we selected 316 firms that collaborated for innovation with other organizations in the past three years. In comparison with the sampled (675) firms, χ^2-tests indicated that this selection was similar in terms of industries ($p = 0.75$) and size classes ($p = 0.63$).

In the internet survey, respondents were asked about their innovation collaboration partners over the previous three years. More specifically, they were asked to indicate where their collaboration partners were located (city and country) and to identify the type of partner (university, public research organization, professional education institute, competitor, customer, supplier or consultancy firm). This manner of questioning introduces a multilevel perspective to our data – i.e. firms provided data on multiple partners. Morever, it allows us to construct a dependent variable which is relatively uncommon in two ways. Firstly, our unit of analysis is the collaboration and not the firm, as is often the case in omnibus innovation surveys such as the European Community Innovation Surveys (CIS). Secondly, we are able to measure geographical distance on the ratio level and operationalise it in kilometers, as approximate Euclidean distance. Current innovation surveys do not measure geographical distances with this detail (OECD, 2005). Past versions of the Dutch CIS, for example, have explored the geographical dimension of innovation collaboration in terms of arbitrary cut-off points (e.g. 'was your collaboration partner located within a radius of 50 kilometers of your firm?'). Other surveys have operationalised distance with ordinal measures. For instance, Drejer and Vinding (2007) explored the propensity to collaborate 'regionally', 'nationally' and 'internationally' in a sample of Danish firms.

Altogether, respondents provided data on 1 245 collaboration partners. Table 1 provides descriptive statistics for our dependent variable and for the explanatory variables that were used to test the relationship between absorptive capacity and geographical distance. Whilst the dependent variable is measured at the level of the specific collaboration partner ($n = 1245$) all other variables are measured at the firm level ($n = 316$). As mentioned above, respondents indicated the location of their collaboration partners (town and country). On average, respondents provided details for 3.94 collaboration partners, with a maximum of 13 identified partners. We remark that the sample consists of highly innovative firms for whom external collaboration appears relatively commonplace. Drawing on a route planning software program we computed the approximate geographical distance to each collaboration partner. If collaboration partners were settled in the same town, the geographical distance was assumed to be one kilometer.

table 1. Variables and descriptive statistics

Variables	Description	descriptives[a]
partner level (n = 1 245):		
geographical distance	distance to collaboration partner (in km)	M = 583; SD = 1 932 skewness = 4.8; kurtosis = 23.3
firm level (n = 316):		
R&D expenditures	R&D expenditures (in €)	M = 351 867; SD = 590 187 skewness = 3.4; kurtosis = 13.7
R&D intensity	share of R&D expenditures in total revenues	M = 0.25; SD = 0.27 skewness = 1.5; kurtosis = 1.1
type of industry	classification of seven industries	manufacturing of chemicals, rubbers and plastics (9%) machinery and equipment (21%) other manufacturing (8%) technical wholesale (9%) IT and telecom services (21%) engineering and commercial R&D (25%) other services (7%)
firm size	number of employees in full-time equivalents	M = 22.5; SD = 29.6 skewness = 2.5; kurtosis = 7.9
urban area	location in urban area (Dutch G50 classification of urban areas)	rural area (56%) urban area (44%)
market reach	number of foreign customers among three largest customers	M = 0.73; SD = 1.01 skewness = 1.1; kurtosis = 0.0

[a] M = mean, SD = standard deviation.

The average distance to a collaboration partner was 583 kilometers. However, most partners were located in a radius of 150 kilometers[3], implying that relative geographical proximity is typical for the majority of innovation collaborations of high-tech small firms. In total, 78.6% of partners were located in the Netherlands. However, firms also recorded some very distant partners – the most distant being located at approximately 17 820 kilometers. In addition to Dutch organisations, collaborative partners were located in Germany (6.2%), Belgium (2.3%), United States (2.3%), United Kingdom (1.8%), France (1.1%) and 31 other countries, including, for example, Canada, China, Denmark, Japan, Russia and Spain.

To proxy absorptive capacity we used two alternative indicators: R&D expenditures and R&D intensity. Cohen and Levinthal (1990) regarded R&D as central to their conceptualization of absorptive capacity – indeed, their seminal work was explicitly concerned with elaborating R&D as both a source of innovation and means of enhancing the firm's ability to learn. R&D expenditures broadly capture the volume and quality of

[3] Approximately 72% of partners were within 150km. The median distance to partners was 82km.

human capital and other expenses that may enhance firms' ability to recognize, adopt and apply external knowledge. On average, respondents spent €351 867 per annum on R&D[4]. The alternative indicator, R&D-intensity, measures the share of R&D expenditures in total annual sales revenues. Rather than the volume of human capital, this measure reflects the importance of R&D as compared to firms' other activities. The average respondent had spent 25% of its revenues on R&D in the past year. The use of R&D as a proxy for absorptive capacity is well established in the literature (Zahra and George, 2002). Although there are rightly concerns about the use of R&D measures in samples of small firms (Muscio, 2007), this limitation does not apply to the current sample of high-tech small firms (R&D-performers by definition).

Our control variables included sector dummies, firm size, urban location and market reach. Firstly, sectors have been demonstrated that the geographical clustering of business networks is dissimilar across industries (Bottazzi, 2001). The same applies to the nature of knowledge, including the relative emphasis on tacit or codified knowledge (Marsilli, 2002). Dummies were included for manufacturers of chemicals, rubbers and plastics (NACE codes 23-25), machinery and equipment (NACE 29-33) and other manufacturers, and also for high-tech small firms in services, including technical wholesale traders (NACE 51.8), IT and telecom firms (NACE 64.2 and 72) and engineering and commercial R&D services firms (NACE 74.2 and 73). Other services firms were the reference group. Secondly, for size it has been suggested that smaller firms are more tied to their territories (Torré, 2008). Limited financial and human resources (for search and coordination) may force smaller firms to locate close to organistions with whom they wish to exchange knowledge. Thirdly, a dummy was included to indicate whether the firm was located in an urban area. Following Feldman (1994), distant collaboration may be a response to resource deficiencies in the local area. We employed the Dutch G50 classification of largest cities (van Oort, 2004) to construct this dummy variable for local munificence. The diversity of knowledge found in urban areas should reduce the impetus to search for distant innovation partners. Finally, we controlled for firms' market reach. Previous work demonstrated clear links between the reach of product markets and innovation collaboration (Arndt and Sternberg, 2000) and between innovation and exporting (Roper and Love, 2002). Operating in geographically dispersed product markets likely eases firms' ability to find and benefit from distant innovation collaboration. In the survey respondents had indicated if they were exporting firms and, if yes, in which countries their three most important customers (in terms of revenues) were settled. We computed an indicator that counts the number of foreign organizations in firms' three major customers. On average, respondents reported 0.73 of such foreign customers (i.e. 58 percent had none, 20 percent reported one foreign customer, 12 percent had two, and ten percent had three of such customers).

Log transformation was applied to all variables which were not normally distributed (see table 1): geographical distance, R&D expenditures and firm size. In particular, the geographical distance variable was highly skewed, since most reported collaboration partners were Dutch and, additionally, any transatlantic collaboration increased the distance substantially. In addition, we computed the log-odds ratio for R&D-intensity – defined as log(R&D-share/1 – R&D-share) – to obtain a continuous and normally distributed variable.

[4] The median expenditure was €127 500.

After these transformations, the variables satisfy all basic assumptions of the regression models presented hereafter. Finally, we specified the whole dataset at the level of the 1 245 identified partners, i.e. all firm-level variables are identical for collaboration partners identified by the same respondent.

Correlations between the transformed variables are presented in table 2. The largest single correlation is between log transformed firm size and R&D-expenditures. The reported correlations do not indicate serious concerns for multicollinearity. As a rule-of-thumb, multicollinearity problems are most likely when correlations exceed absolute values of 0.80 (Hair et al., 1998: p. 189).

table 2. Correlation matrix (n = 1 245)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
(1) log geographical distance											
(2) log R&D expenditures	.17										
(3) log odds R&D intensity	.10	.22									
(4) industry: manufacturing of chemicals, rubbers and plastics	.02	.02	-.08								
(5) industry: manufacturing of machinery and equipment	.04	.18	.01	-.17							
(6) industry: other manufacturing	.05	.06	-.22	-.09	-.14						
(7) industry: technical wholesale services	.06	-.10	-.16	-.10	-.16	-.09					
(8) industry: IT and telecom services	-.16	-.19	.02	-.15	-.24	-.13	-.15				
(9) industry: engineering and commercial R&D	-.01	.00	.22	.21	-.33	-.18	-.20	-.30			
(10) log number of employees	.07	.65	-.42	.09	.08	.15	.02	-.07	-.15		
(11) urban area	-.12	-.07	.14	.08	-.11	-.11	.06	.13	-.02	-.15	
(12) market reach	.22	.18	-.12	.16	.14	.09	-.04	-.20	-.08	.14	.00

Absolute values $.06 \leq r < .08$ are significant at $p < 5\%$
Absolute values $.08 \leq r < .10$ at $p < 1\%$
Absolute value $r \geq .10$ at 0.1%.

RESULTS

Since our data have a nested structure (multiple partners per firm), we engaged in multilevel regressions to test our hypothesis. To examine if our data call for multilevel modeling, we conducted various a priori tests as recommended by Snijders and Bosker (1999). The intraclass correlation coefficient - indicating the share of variance in geographical distance that is due to the fact that firms identified multiple partners – was 0.17 and positive, while one-way analysis of variance revealed significant differences in the distance to collaboration partners of different respondents ($F = 1.84$, $p < 0.001$). This implies that ordinary least squares estimates would provide inaccurate standard errors and false tests of significance (Snijders and Bosker, 1999).

Multilevel regression models provide estimates of higher (firm) level variables on lower (partner) level outcomes, while accounting for the non-independence of observations within firms. A simple variant is the random intercept model. Such models treat differences between firms as a source of variance in the intercept of the regression equation. More complicated are random slope models, which also allow effect parameters to differ across firms (Snijders and Bosker, 1999, p. 38-85). Here, we first estimated random intercept models and subsequently checked if random slope models would provide a better fit. As this was not the case, we only present our random intercept estimates. We subsequently estimated the following models:

- An empty model (no independent variables) to obtain a benchmark against which the subsequent model is compared, and that serves as a baseline to compute pseudo-R^2 (model I)
- A model with all control variables: industry dummies, size, urban area and market reach (model II)
- A model with all control variables and R&D-expenditures (model III)
- A model with all control variables and R&D-intensity (model IV).

In table 3 we show our findings. As multilevel regression uses maximum-likelihood estimators, model fit is assessed by comparing deviance measures of subsequent models: a decrease of the deviance measure (Δdev) is related to Δdf (degrees of freedom) and tested against a χ^2-distribution. Model I gives an initial deviance value of 3 309.61.

table 3. Multilevel regression models of geographical distance (n = 1 245)

	Models			
	I	*II*	*III*	*IV*
Parameter estimates:				
industry: manufacturing of chemicals, rubbers and plastics		-0.06	-0.06	-0.07
industry: manufacturing of machinery and equipment		-0.09	-0.11	-0.14#
industry: other manufacturing		-0.06	-0.04	-0.06
industry: technical wholesale trade		-0.01	0.03	0.00
industry: IT and telecom services		-0.18*	-0.14#	-0.18*
industry: engineering and commercial R&D services		-0.09	-0.09	-0.13
log number of employees		-0.02	-0.09	0.06
urban area		-0.11*	-0.13**	-0.14**
market reach		0.21**	0.21**	0.23**
log R&D expenditures			0.19**	
log odds R&D intensity				0.10^
Model fit:				
deviance (-2LL)	3 309.61	2 915.30	2 543.41	2 774.73
Δ deviance (-2LL)		394.31	371.89	140.57
Δ df		9	1	1
Significance		**	**	**
pseudo-R^2		0.16	0.20	0.17

** $p < 0.001$, * $p < 0.01$, ^ $p < 0.05$, # $p < 0.10$.

In model II, entering the control variables significantly improves model fit (Δdev = 394.31 with Δdf = 9, $p < 0.001$). Pseudo-R^2 is computed according to the guidelines of Snijders and Bosker (1999) and proxies the explained share of variance in geographical distance at the level of firms. We find that IT and telecommunication service firms are less likely to collaborate at great distance ($b = -0.18$, $p < 0.01$). For firm size no significant result is found. This may very well be a consequence of the nature of our sample – all innovative, R&D-performing firms by definition, and dissimilar from previous samples used to demonstrate a connection between firm size and innovation collaboration (e.g. Tether, 2002). For urban areas, our presupposition of less geographical reach to collaboration partners is confirmed ($b = -0.11$, $p < 0.01$). For market reach, we also find the anticipated significant connection ($b = 0.21$, $p < 0.001$).

Model III tests our hypothesis that absorptive capacity and geographical distance are connected variables. The hypothesis is strongly supported. Adding R&D expenditures to the equation significantly improves model fit ($\Delta dev = 371.89$, $p < 0.001$). The standardized effect parameter is also significant ($b = 0.19$, $p < 0.001$) while controlling for industries, size, urban location and market reach. Next, model IV may be regarded as a robustness check, i.e. we find a similar result when applying a different absorptive capacity indicator. R&D intensity also increases model fit and gives a significant effect parameter. Compared to the third model, the significance is less pronounced but still present, and probably a consequence of the fact that R&D intensity does not capture the volume of firms' investments.

We continued our robustness checks by estimating a range of other models. As noted, random slope models did not make any difference. We also explored the consequences of including more control variables. For instance, there is some suggestion in the literature that partner type might influence the reach of collaboration (Oerlemans et al., 2001). In the survey, respondents had provided data on partner types (such as universities, customers, suppliers, etc), but entering these as controls did not affect our results.

CONCLUSIONS

It is often taken for granted that geographical proximity is necessary for successful collaboration in innovation projects – most especially for small firms. Drawing on recent literature, we noted that this view may be challenged, i.e. geographical distance can be compensated by other forms of proximity. Principal amongst these is cognitive proximity, which may be achieved as a direct outcome of investments in firms' absorptive capacities. Accordingly, we tested the hypothesis that a firm's absorptive capacity is positively related to the geographical distance to innovation partners, and drawing on a sample of Dutch high-tech small firms, we found strong empirical support. This empirically confirms Boschma's (2005) proposition that geographical proximity is neither a sufficient nor a necessary condition for innovation collaboration. Of course, geographical proximity may still ease the effectiveness of collaborative efforts. Indeed, our analyses noted that most partners were located 'fairly' close – i.e 78.6% of all reported partners were Dutch and, for international partners, location in neighbouring countries such as Germany and Belgium was most common. It is reasonable to conclude that firms will choose local partners in the first instance. Likewise, Moodysson and Jonsson (2007) noted similar aspirations amongst Danish and Swedish biotechnology firms. However, 'when it comes to the need for highly specialized, qualified and sophisticated services, costs of overcoming distance play only a modest role, and quality, not proximity, is the decisive factor' (Drejer and Vinding, 2005:

p. 893). Given that our models controlled for local munificence and the geography of product markets, our finding suggests that investments in absorptive capacity enable effective search and reach, through reducing cognitive distances. And, in this way, help to overcome the barriers to knowledge exchange imposed by large geographical distances.

Our findings have implications for both managers and policy makers. For managers, our results suggest that specific efforts to increase absorptive capacity are beneficial to improve firms' ability to recognize, adopt and apply external knowledge from a geographically broader area. In increasingly dynamic business environments this is a valuable capability. Absorptive capacity prevents firms from becoming locked in to a specific geography, and to too-familiar collaboration partners, running the risk of failing to recognize or master new breakthrough technologies. In an Open Innovation world (Chesbrough, 2003) this is increasingly important. Whilst Open Innovation concepts imply a diminishing ability to benefit directly from own R&D, absorptive capacity becomes correspondingly more important as a means to realise purposive inflows of external knowledge. In this context, one might point to evidence that many firms have recently de-emphasized their fundamental research activities because they believed themselves less able to appropriate its results as innovation processes became more open (EIRMA, 2004). Managers should be aware that such strategies will, in the longer term, also affect their organization's ability to benefit from external knowledge.

Implications for policy makers are twofold. Firstly, although our data suggested that high-tech small firms usually find their partners at fairly close distance, there were a substantial number of exceptions. Respondents were certainly not constrained to work only with close partners, and those firms with a higher absorptive capacity managed to collaborate at greater distance. This implies that policy instruments to stimulate interaction do not necessarily need to be geographically focused. In fact, it may be remote collaboration that needs to be stimulated. Yet, current cluster policies are predisposed towards local networking while extra-local knowledge exchanges are overlooked. As Torré (2008) summarises, 'the search for synergies between local actors has become the basis for most policies of local development' (p. 875). Policies should also aim for firms' capabilities to search for, recognize, evaluate, assimilate and exploit geographically distant knowledge. This is likely to be particualry important in areas where innovation resources are relatively scarce, such as non-urban settings. Secondly, for innovation policies with a transnational component our recommendation speaks to current ambition. Given the consistent correlation between firm size and absolute R&D expenditures (Nooteboom, 1994), one should not anticipate many small firms successfully applying for European subsidy schemes in support of collaborative R&D. The EU Framework Programmes for research, technology development and demonstration activities, for example, face enduring problems with attracting participation of small firms (European Commission, 2002). Our empirical results suggest that this makes sense. Given limited scope to invest in R&D and reliance upon a narrow pool of labour, small firms generally lack the absorptive capacity to enable collaboration at greater distance. Objectives to involve minimum numbers of small firms in the EU Framework Programmes may simply be too ambitious, or should be connected to regional/national schemes which first try to improve the absorptive capacity of such firms (by stimulating their R&D efforts and/or employment of highly-educated staff, for example).

We admit that our work contains limitations, and some of them directly suggest avenues for future research. A first remark is that cognitive proximity was central to reasoning a positive correlation between absorptive capacity and the geographical reach of innovation collaborations. Yet, this subject was not available in our empirical data. Rather, on the basis of recent theoretical and empirical expositions on related issues, we inferred cognitive proximity as the principal learning effect of R&D. In this, we were constrained by data collected for a broader purpose. For future work, it would clearly be preferable to more directly, and more precisely, measure cognitive distance. Relatedly, we remind that Boschma (2005) stressed other types of proximity which may also be influential to explain the reach of innovation collaboration. Previous studies arrived at dissimilar results of the maximum geographical distance for knowledge spillovers to occur, e.g. 75 miles (Varga, 1998), 300 km (Bottazi and Peri, 2003) or 400 km (Greunz, 2005). This is taken to represent the distance one might reasonable travel for a business meeting and return on the same day. It is clear that simple geographical distances remain limited in their ability to explain when and why innovation collaboration can take off. Rather some measure of 'functional proximity' may be more appropriate. Functional proximity, as Moodysson and Jonsson (2007) define it, refers to 'physical distance affected by mobility' (p. 118). A reasonable analogue may be 'accessibility', whereby geographical distance is tempered by time and cost dimensions.

Another limitation revolves around the conceptualization and measurement of absorptive capacity. Where definitions of absorptive capacity are offered, there is little consistency in the literature (Xia and Roper, 2008). Zahra and George (2002) for instance sought to distinguish between potential absorptive capacity (PACAP) and realized absorptive capacity (RACAP), where the former is concerned with the acquisition and assimilation of external knowledge, and the latter on transformation and exploitation. Here, our conceptualisation leans towards PACAP – we did not attempt to measure the outcomes of collaboration. Moreover, our measurement is narrow in the sense that it is concerned solely with R&D expenditures. However, whilst acknowledging that absorptive capacity may have other bases (such as employee skills), and that these may be particularly relevant in non-high-technology small firm settings, R&D expenditure is undoubtedly the most common proxy for absorptive capacity, and provides a stronger base for cross study comparability. Regardless, more nuanced measures of absorptive capacity are necessary to illuminate the relationships further. Relatedly, our data addressed only high-tech firms. Although this group is the main target of many innovation policy instruments in all developed countries, high-tech small firms are only a fraction of the business population. For non-technology-based small firms, one doubts that R&D expenditure will be a very useful measure of absorptive capacity. Rather, broader indicators of know-how (such as training expenditures, workforce skills, or marketing budgets) may be more useful. Investigation of less specific samples is called for.

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